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Modeling as a New Literacy

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Abstract. In this paper, we argue that modeling and simulation, being an integral part of computer science (CS), can contribute to the learning and understanding of phenomena in other (STEM)¹ disciplines. Subsequently, we discuss agent based modeling (ABM), a simulation modeling technique suitable for use in schools where students' knowledge of mathematics and phenomena they study is limited.

1 Modeling in School

Following the increasing availability of powerful computers in schools, a number of initiatives have been employed to aid students' learning in various (STEM) disciplines through the use of computer models for e.g. physics [8; 9] material science [3] and biology [1]. Nowack and Caspersen [5] argue why they „believe understanding and creating models are fundamental skills for all pupils as it can be characterized as the skill that enable us to analyze and understand phenomena as well as design and construct artifacts.” Wilensky claims, „Computational modeling has the potential to give students means of expressing and testing explanations of phenomena both in the natural and social worlds” [10]. Granger goes even further and declares, „Modeling is the new literacy” [7]. While that statement can be a subject to a debate, it is certain that modeling, together with simulations, can be a valuable part of a (STEM) curriculum. This fact is recognized in the new Dutch curriculum for the elective CS course in the grades 10 through 12 of the senior general secondary education (Dutch: HAVO) and pre-university education (Dutch: VWO) by including modeling in the core curriculum and computational science (i.e. modeling and simulations) in the elective part of the curriculum [2]. The rationale for the inclusion of these learning objectives into the curriculum is guided by the fact that many students electing the CS course are going to pursue scientific and engineering careers outside of CS, and CS can provide them with skills that allow them to formulate problems in such a way that these can be solved with the help of a computer. In other words, this is recognition of the fact that CS can provide methods and ways of thinking that can contribute to the understanding of phenomena in other (STEM) disciplines.

¹ Not only STEM, but across a whole range of disciplines.

2 Agent Based Modeling

STEM disciplines often employ scientific modeling, „the generation of a physical, conceptual, or mathematical representation of a real phenomenon that is difficult to observe directly” [6]. Building physical models in a (STEM) classroom has its merits but generally does not happen in a CS class, and finding a non-trivial mathematical representation of an arbitrary complex phenomenon is often beyond reach of K-12 students. Conceptual representation, however, is well within reach of these students when appropriate techniques and tools are used. Conceptual representation with the aid of computing, where a model has a form of a computer program and is used to run simulations, is simulation modeling. There are three methods in simulation modeling:

- System dynamics, associated with high level of abstraction where the individual objects are aggregated. The models are described in terms of coupled nonlinear, first-order differential equation. Solving these equations is often non-trivial and requires the use of numerical methods [4]. High demands on mathematical knowledge deem this type of modeling out of reach for most secondary CS students, as observed by the author in her classroom and corroborated by Wilensky [10].
- Discrete event modeling, where the system modeled is considered to be a process, „i.e. a sequence of operations being performed across entities”. The level of abstraction is lower as „each object in the system is represented by an entity or a resource unit” that are passive, i.e. the process flowchart defines what happens to them [4].
- Agent based modeling (ABM), which is made possible with recent growth of availability of CPU power and memory. It does not assume any particular abstraction level. Agents have their properties and behavior and one can start building a model by identifying agents and describing their behavior even without knowing how a system behaves as a whole. ABM makes it possible to model systems that are difficult to capture with older modeling approaches [4].

In our view, the last two characteristics of the ABM make it a suitable modeling method for our students who often lack deep understanding of the phenomena they model and make models specifically to deepen their understanding. To conclude, we consider conceptual representation which could be realized through the employment of ABM methods and software, in which „you give computational rules to individual agents and then observe, explore analyze *the resultant aggregate patterns* [10], suitable for use in secondary CS class „because the individual-level behavior of agents is relatively simple, [and] ABMs feature relatively simple computer programs that control the behaviors of their computational agents” [11].

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